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(54) **DEVICE FOR MEASURING NEGATIVE PRESSURES IN AN EXTRACORPOREAL BLOOD CIRCUIT**

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(52) **U.S. Cl.** **210/90**; 210/97; 73/715; 73/716; 73/717; 73/723

(58) **Field of Search** 210/86, 90, 97; 73/715, 716, 717, 723, 1.57, 1.68, 49.1

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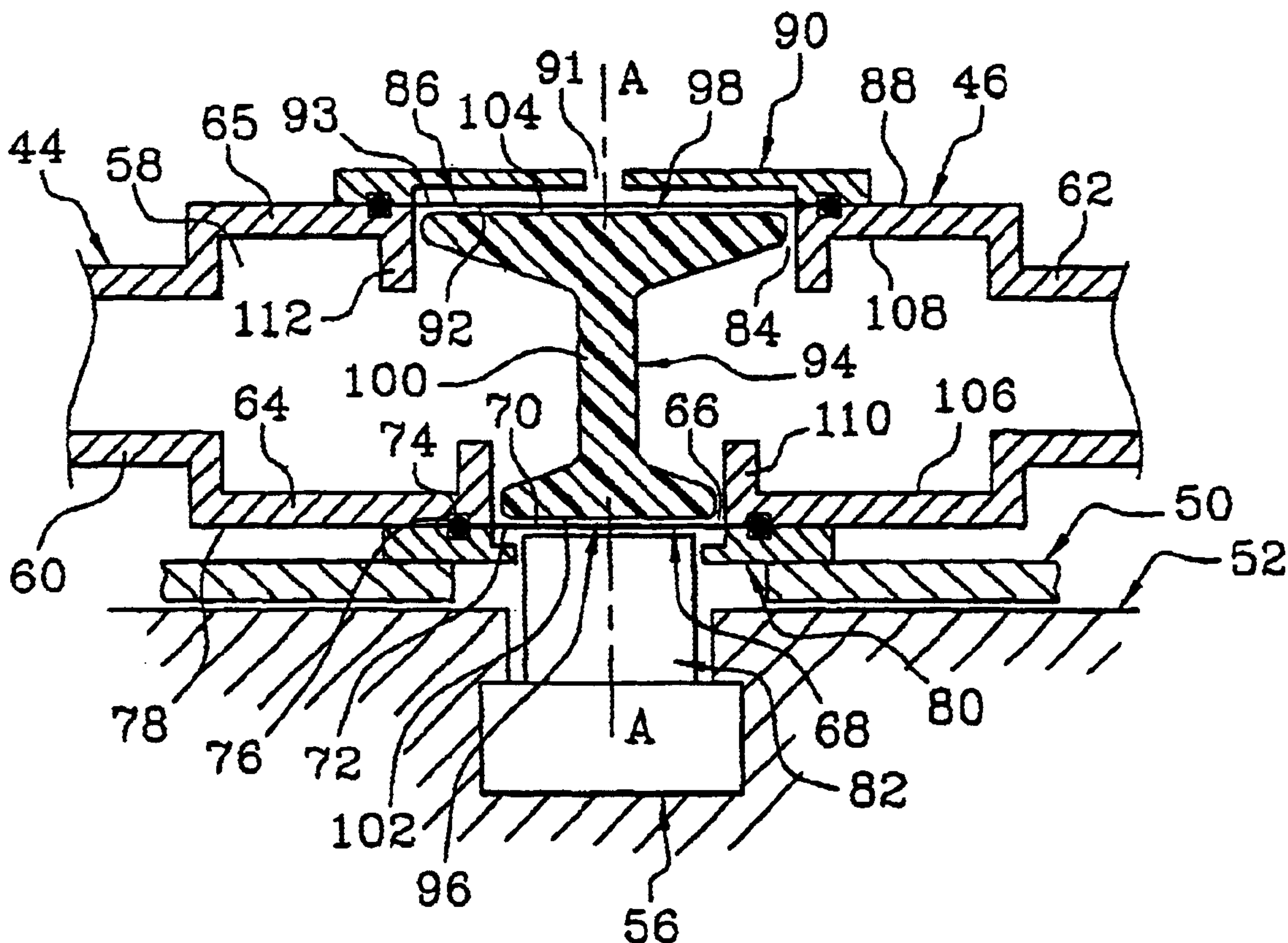
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(57) **ABSTRACT**

A device for measuring the pressure of blood in a pipe (44) of an extracorporeal blood circuit, includes a pressure measurement section (46) having a compartment (58) which is delimited especially by a main wall (64) and by a secondary wall (65) facing it. The two walls (64, 65) have a hole (66, 84) which is closed by a closure element (68, 86) which can be elastically deformed under the effect of the blood pressure, and the compartment (58) has a spacer (94) which transmits the movements from the closure element (86) of the secondary wall (65) to the closure element (68) of the main wall (64), so that a load sensor (56) can measure a force which corresponds to a so-called “negative” blood pressure.

13 Claims, 3 Drawing Sheets



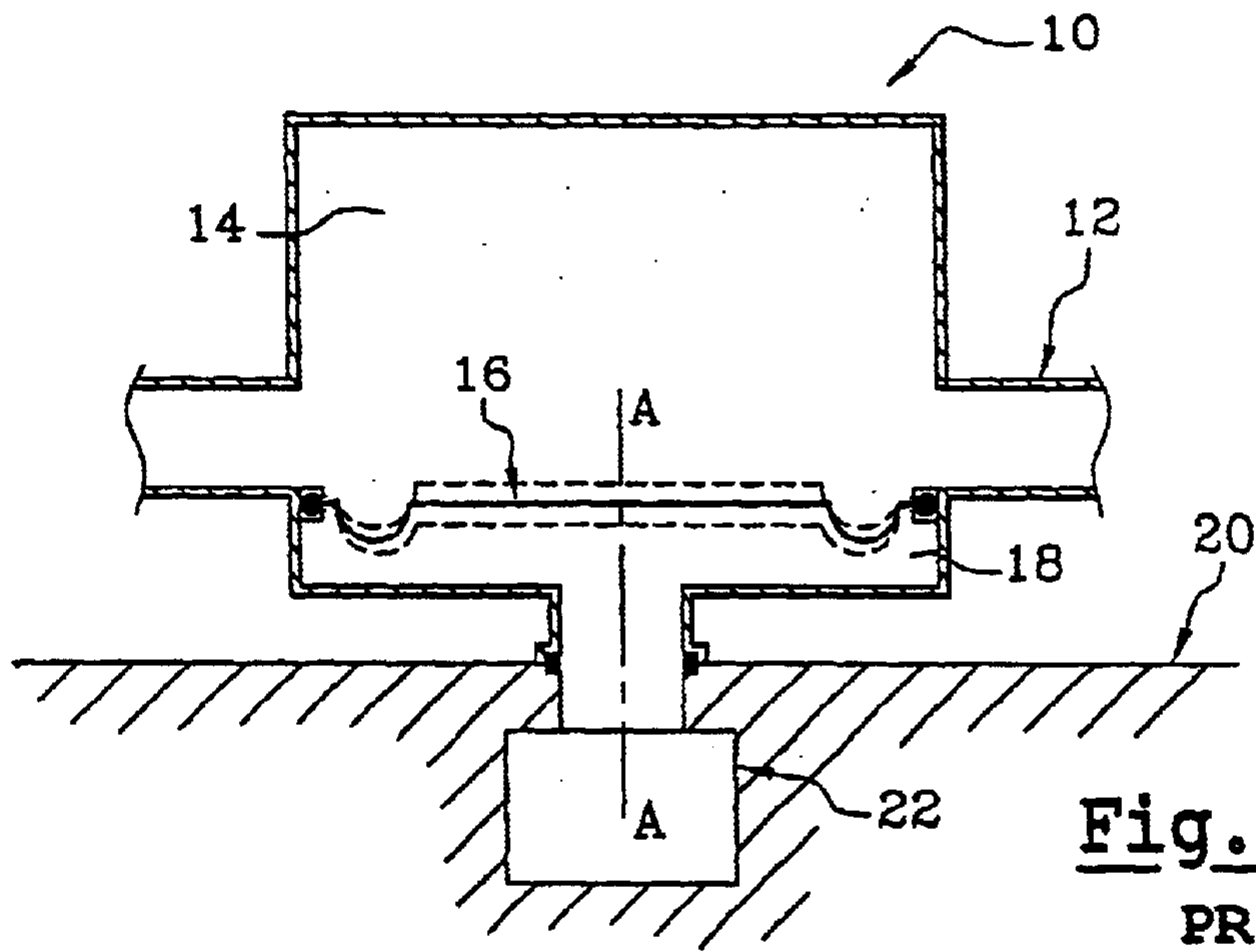


Fig. 1
PRIOR ART

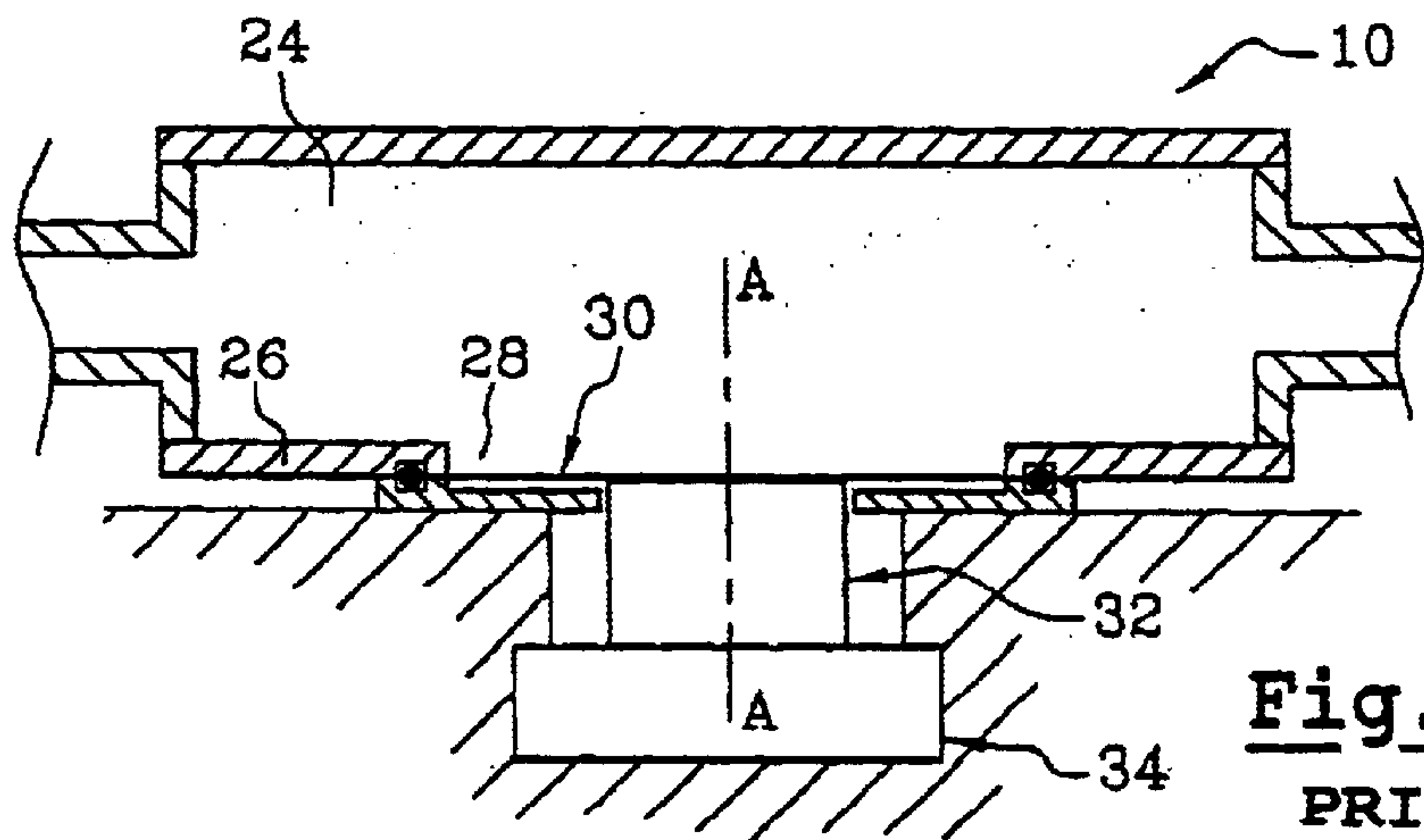


Fig. 2
PRIOR ART

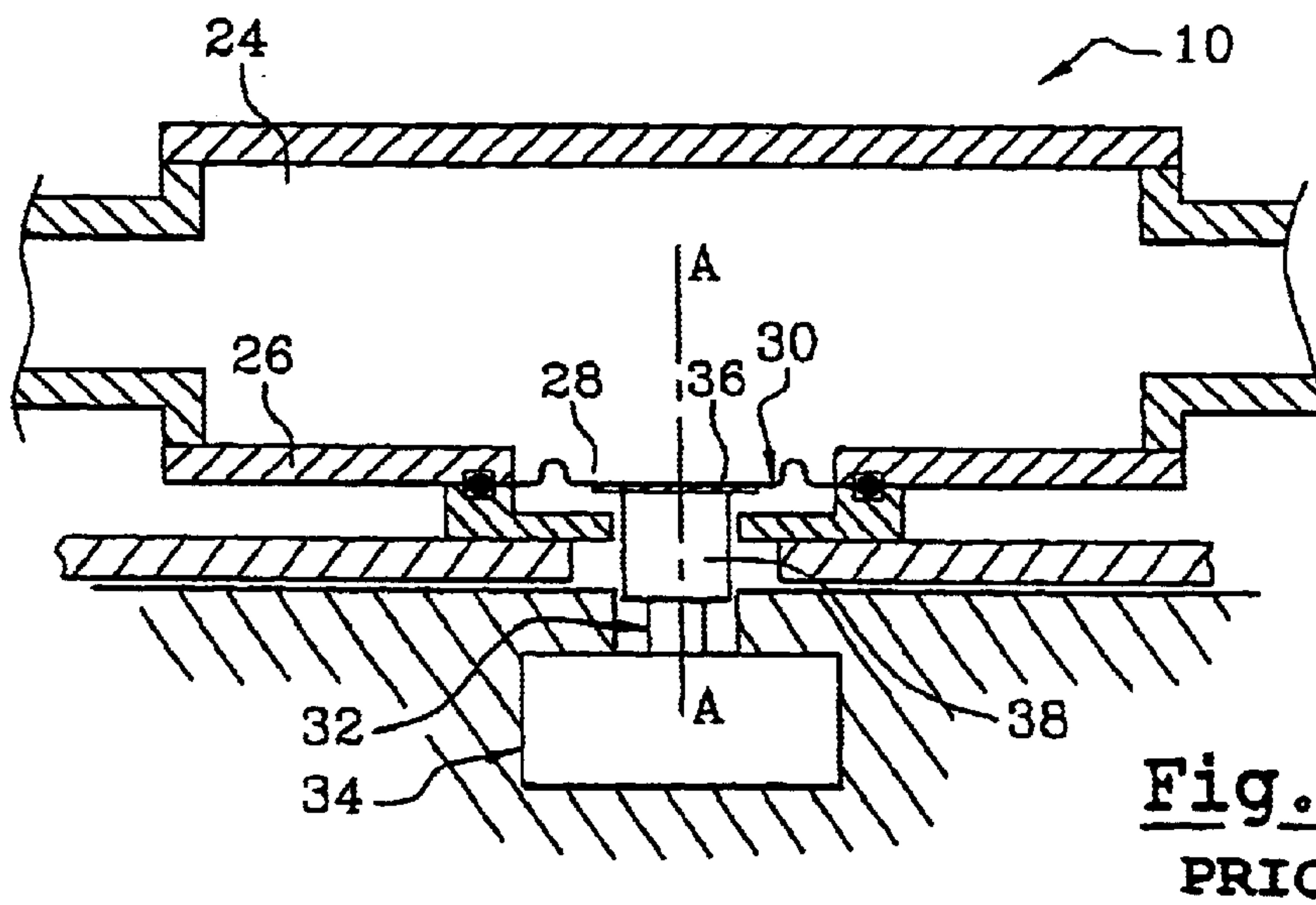
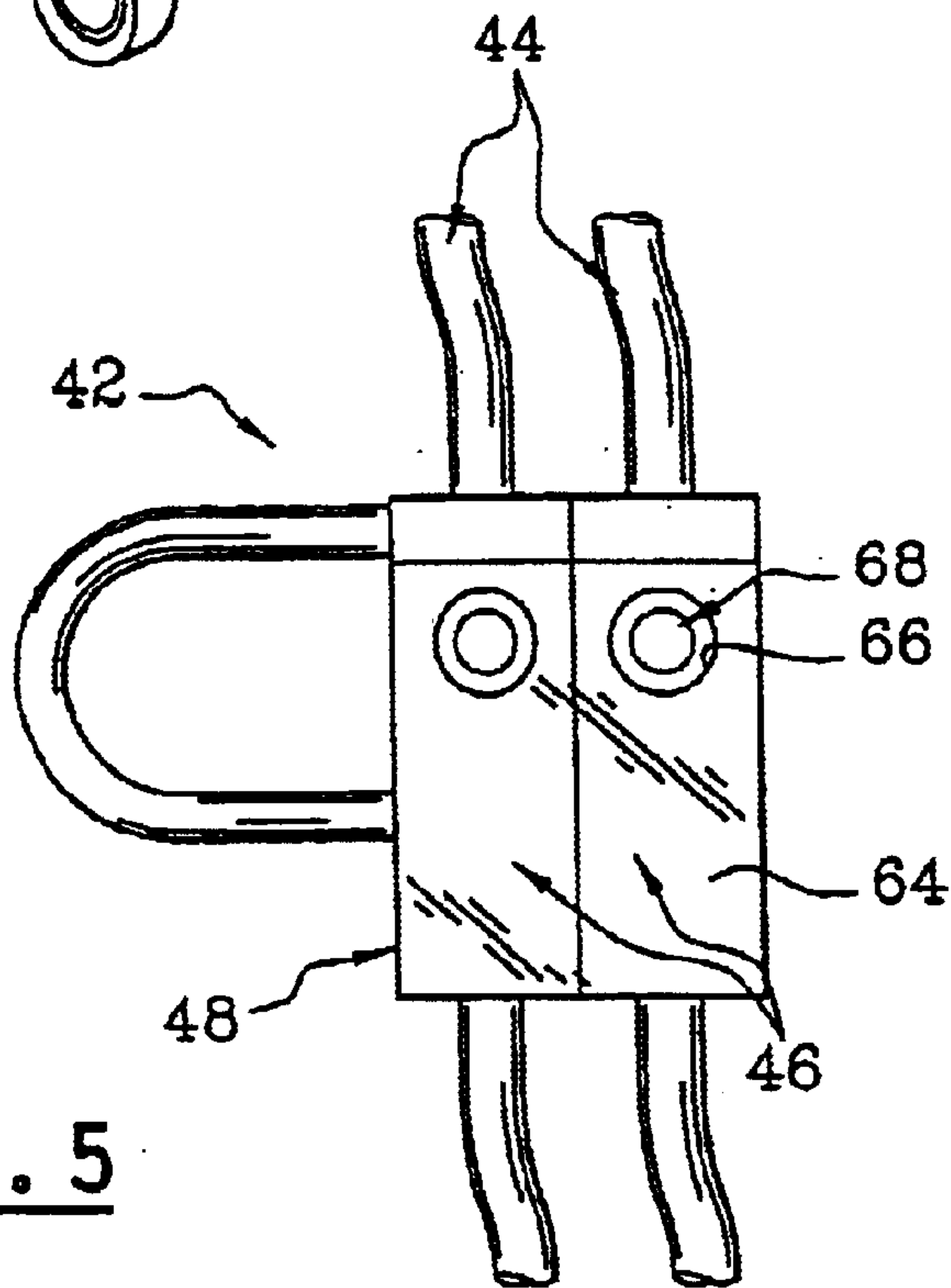
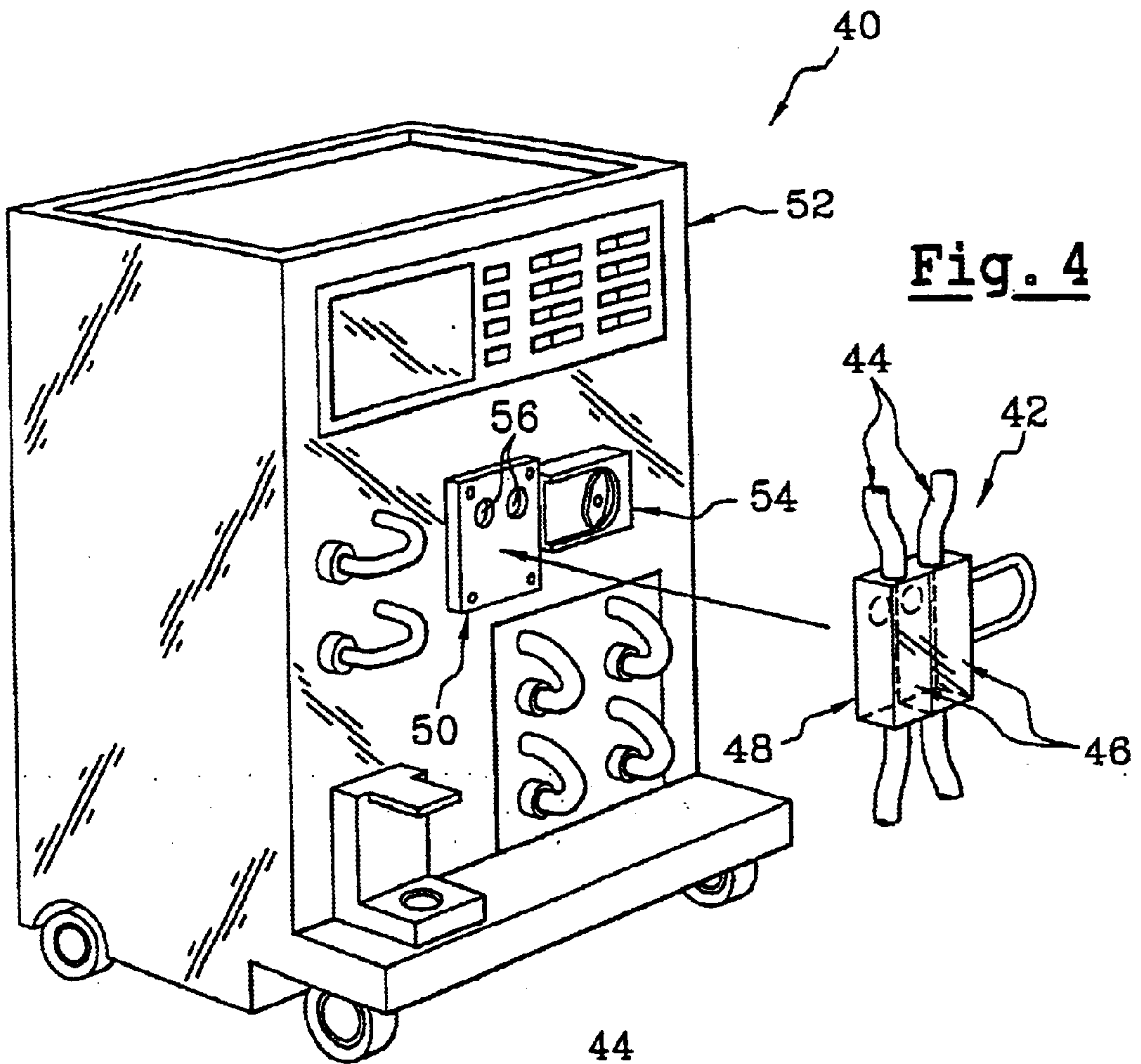


Fig. 3
PRIOR ART



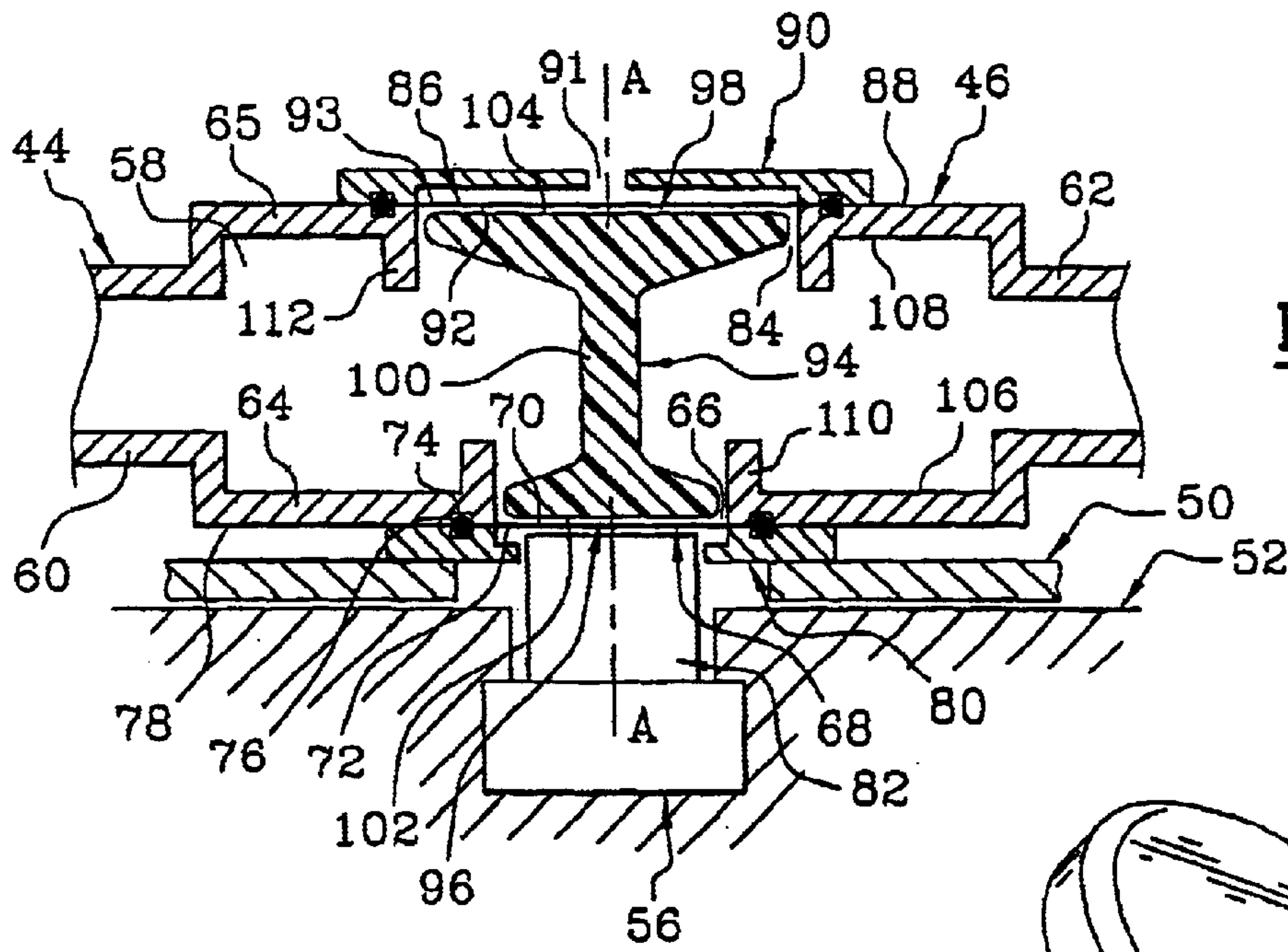


Fig. 6

Fig. 7

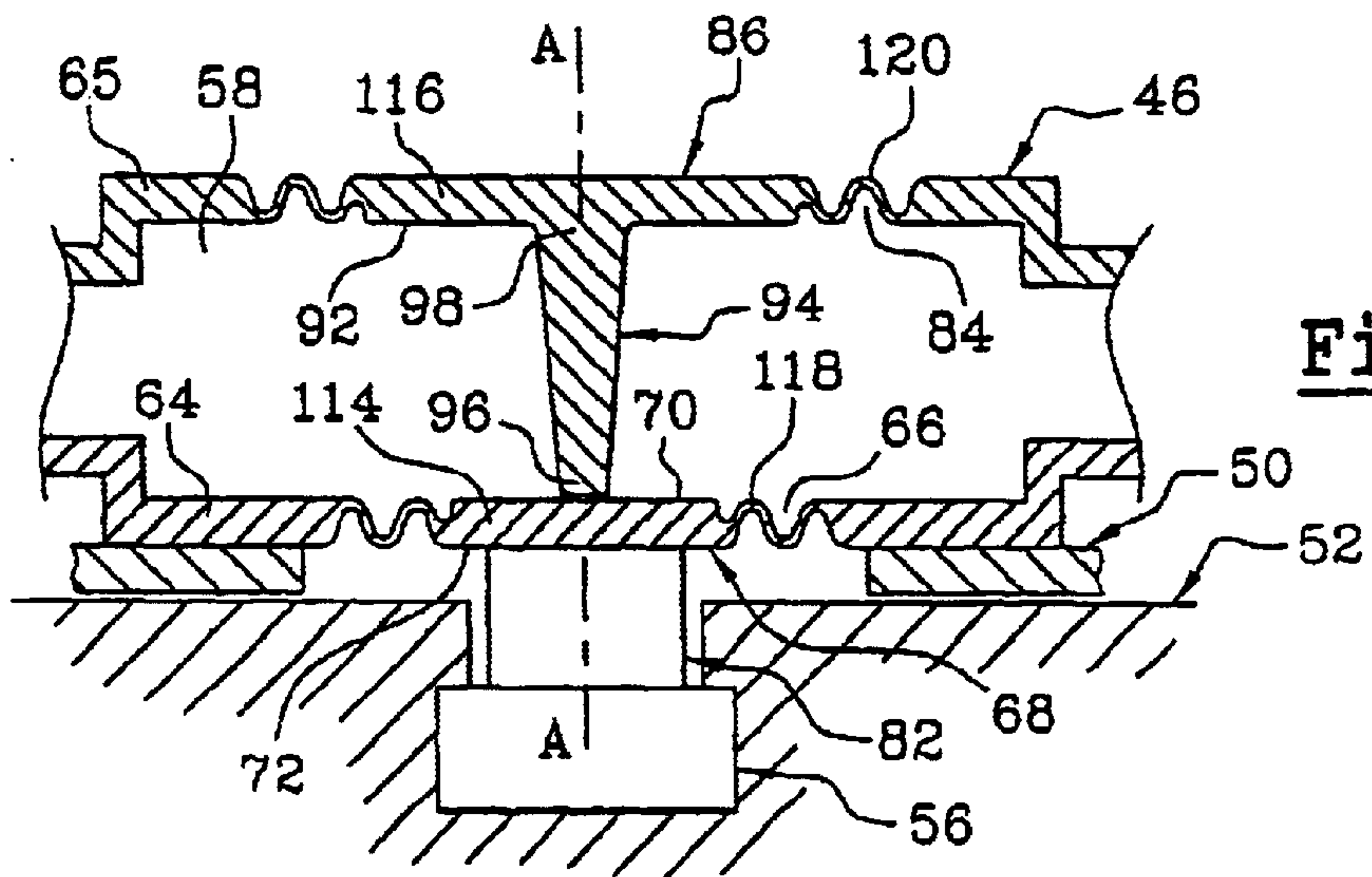
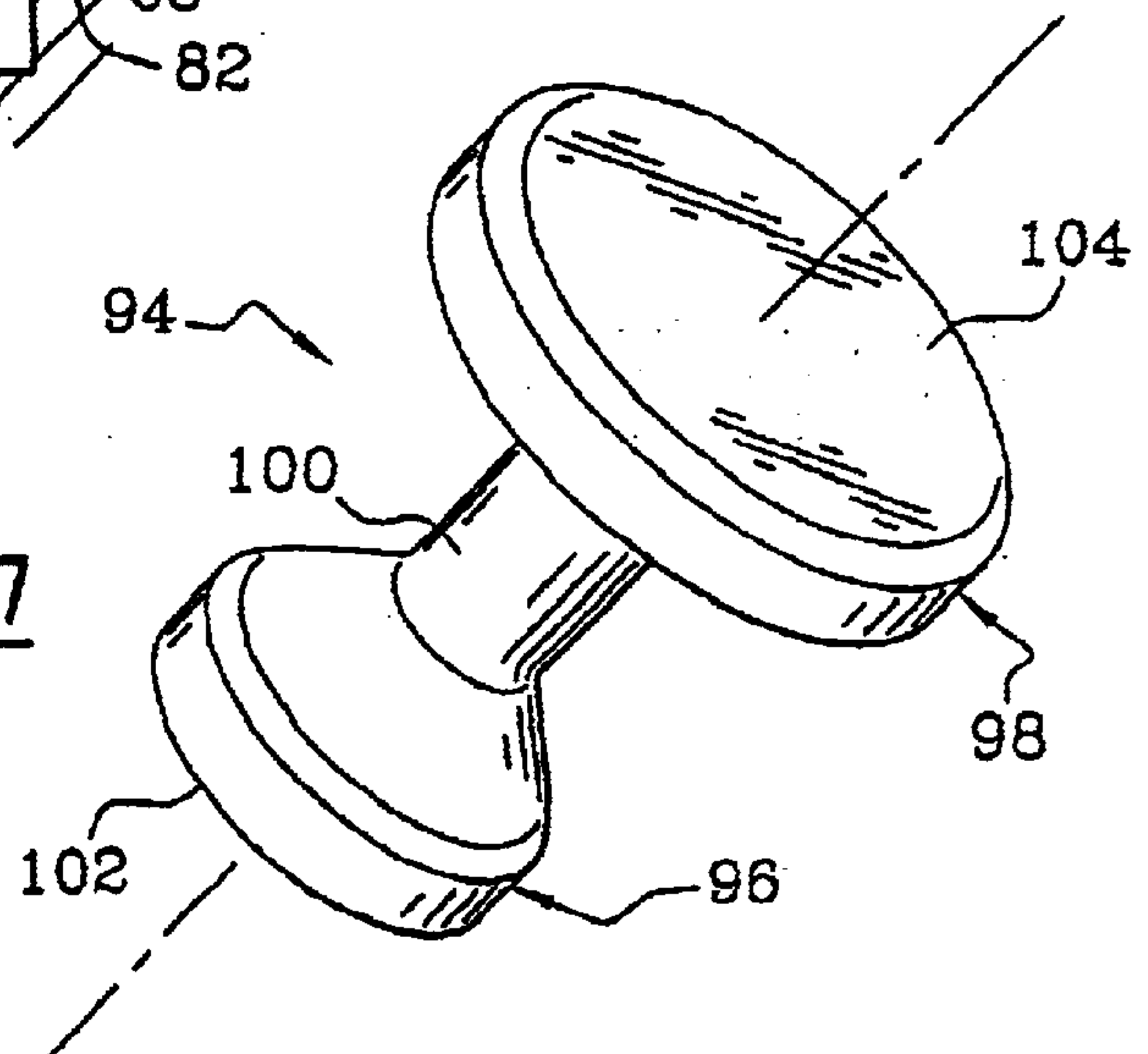


Fig. 8

DEVICE FOR MEASURING NEGATIVE PRESSURES IN AN EXTRACORPOREAL BLOOD CIRCUIT

FILED OF THE INVENTION

The present invention relates to a device for measuring blood pressure.

More particularly, the present invention relates to a device for measuring the pressure of blood which is used in an extracorporeal blood treatment device in which the blood is taken from a patient in order to be treated then reintroduced into the body of the patient (especially for the purpose of carrying out dialysis) by means of an extracorporeal blood circuit comprising pipes and including at least one section for measuring the pressure of blood circulating in a pipe.

BACKGROUND OF THE INVENTION

A known type of pressure measurement section forms a compartment which is delimited especially by a main wall and by a secondary wall facing it, the two walls being substantially rigid and parallel; the main wall comprises a hole which is sealed by a main closure element, the internal face of which is in contact with the blood and the external face of which is in contact with the ambient air, it being possible to elastically deform or displace the entire main closure element along a deformation or displacement axis which is substantially orthogonal to its general plane, under the effect of the blood pressure; a portion of the external face of the main closure element, in its rest state, is in direct or indirect contact with a load sensor which is able to measure the force applied axially to the internal face of the main closure element by the pressure of the blood, in order to calculate therefrom the value of this pressure.

Generally, this type of extracorporeal blood treatment device comprises a circuit part which is formed from a casing, or cassette, of the "disposable" type, integrating pipes which are connected to the extracorporeal blood circuit.

The pressure measurement section may be an attached module which is mounted in a housing associated with the casing.

The casing is mounted on a support apparatus which comprises, for example, sensors, display means, pumping means, a control interface, an electronic control unit, etc.

In this type of extracorporeal blood treatment device, the blood pressure must be measured without contact between the measuring member and the blood.

Several systems for carrying out this pressure measurement are known.

In a first pressure measurement system, which is shown in FIG. 1, a pressure measurement section 10 in a pipe 12 comprises a measurement chamber 14 in which a membrane 16, or diaphragm, separates the blood flowing in the pipe 12 from the air contained in a compartment 18.

The membrane 16 can be deformed along a deformation axis A—A orthogonal to its general plane, such that it is axially displaced according to the blood pressure in the pipe 12.

The extreme deformation positions of the membrane 16 are shown in dotted lines.

The air compartment 18 is sealed shut when the pressure measurement section 10 is mounted on a support apparatus 20.

The support apparatus 20 comprises a sensor 22 which directly measures the pressure in the air compartment 18.

When the blood pressure changes, the membrane 16 is axially displaced to an equilibrium position in which the pressure is equal on each side of the membrane 16.

The pressure measured by the sensor 22 in the air compartment 18 is therefore equal to the blood pressure in the pipe 12.

By virtue of a suitable geometry, in particular by virtue of a suitable volume of the compartment 18 and a suitable surface for the membrane 16, this first pressure measurement system makes it possible to measure, on the one hand, so-called "positive" blood pressures, that is blood pressures which are greater than a reference pressure, in this case atmospheric pressure, and, on the other hand, so-called "negative" blood pressures, that is blood pressures which are less than the reference pressure.

This measurement system operates correctly provided there are no leaks in the air compartment 18, otherwise the membrane 16 is then displaced to its end stop and it no longer carries out the function of transmitting pressure.

The sealing of the air compartment 18 during mounting of the pressure measurement section 10 on the support apparatus 20 is a weak point of the measurement system.

In particular, the seal may be impaired while the measurement system is in use.

In a second pressure measurement system, which is shown in FIG. 2, the pressure measurement section 10 forms a compartment 24 containing the blood and a wall 26 of which includes a hole 28 which is sealed by a flexible membrane 30.

When the pressure measurement section 10 is mounted on the support apparatus 20, the external face of the central part of the flexible membrane 30 is in contact with a load transmitter 32 which is inserted between the membrane 30 and a load sensor 34.

The load sensor 34 makes it possible to measure the forces applied to the internal face of the membrane 30 due to the effect of the blood pressure in the compartment 24, when the blood pressure is greater than the ambient air pressure.

The blood pressure is calculated from the equation:

$$P = \frac{F - F_0}{S_a} \quad (1)$$

In this equation, F is the force measured by the load sensor 34, F₀ is the force measured in the rest state, that is in the absence of a pressure gradient between the two sides (external and internal faces) of the membrane 30, and S_a is the area of the active surface of the membrane 30.

The area of the active surface S_a of the membrane 30 has a value between the total area of the internal face of the membrane 30 in contact with the blood and the area of contact between the membrane 30 and the load transmitter 32.

For very flexible membranes 30, the active surface S_a is substantially equivalent to the area of contact between the membrane 30 and the load transmitter 32.

This measurement system makes it possible to measure a positive pressure but it does not allow a negative pressure to be measured.

This is because, for negative pressures, the membrane 30 tends to come away from the load transmitter 32. The load sensor 34 can therefore no longer measure the forces which are applied to the membrane 30.

This system has therefore been adapted to measure negative pressures.

In order that the load sensor **34** can continue to measure the forces which are applied to the membrane **30**, when the blood pressure is negative, the membrane **30** is secured in axial displacement to the load transmitter **32**.

Thus, according to an improved embodiment of the second pressure measurement system, which is shown in FIG. **3**, the membrane includes a metal disc **36** on its external face and the load transmitter **32** includes a magnet **38** at its axial end facing the membrane **30**.

The magnetic attraction exerted by the magnet **38** on the metal disc **36** makes it possible to secure the membrane **30** in axial displacement to the load transmitter **32**.

When the pressure is positive, the membrane **30** exerts an axial force which pushes against the load transmitter **32**.

When the pressure is negative, the membrane **30** exerts an axial force which pulls on the load transmitter **32**.

This device for securing the membrane **30** to the load transmitter **32** is expensive since it requires a special membrane **30** fitted with a metal disc **36** and a special load transmitter **32** fitted with a magnet **38**.

The metal disc **36** must have a large area in order to allow effective magnetic coupling.

Furthermore, the membrane **30** experiences a significant jolt when the metal disc **36** "sticks" to the magnet **38** of the load transmitter **32**, which could impair its mechanical characteristics.

The invention aims to remedy these drawbacks.

SUMMARY OF THE INVENTION

For this purpose, the invention proposes a device for measuring the pressure of blood in a pipe of an extracorporeal blood circuit, comprising a pressure measurement section having a compartment which is delimited especially by a main wall and by a secondary wall facing it, the two walls being substantially rigid and parallel, the main wall having a hole which is sealed by a main closure element, the internal face of which is in contact with the blood and the external face of which is in contact with the ambient air, it being possible to elastically deform or displace the entire main closure element along a deformation or displacement axis, which is substantially orthogonal to its general plane, under the effect of the blood pressure, the main closure element being designed to engage with a load sensor so that a portion of the external face of the main closure element, in its rest state, is in direct or indirect contact with the load sensor which can measure the force applied axially to the internal face of the main closure element by the blood pressure, in order to calculate therefrom the value of this pressure, characterized in that the pressure measurement section comprises:

in its secondary wall, facing the hole of the main wall, a secondary hole which is sealed by a secondary closure element similar to the main closure element, the deformation or displacement axis of which is substantially coincident with that of the main closure element, the area of the internal face of the secondary closure element being greater than the area of the internal face of the main closure element, such that when the pressure of the blood is less than the pressure of the ambient air, the axial displacement of the secondary closure element towards the main closure element is greater than the axial displacement of the main closure element towards the secondary closure element;

and comprising, in the compartment, a transmission spacer which, when the pressure of the blood and the pressure of the ambient air are substantially equal, occupies a rest position in which it is in contact by a first axial end with the internal face of the main closure element and, by a second axial end, with the internal face of the secondary closure element;

such that when the blood pressure is less than the ambient air pressure, the spacer transmits the axial displacement, in the direction of the load sensor, from the secondary closure element to the main closure element, so that the load sensor can measure the resultant axial force in order to calculate therefrom the value of the blood pressure.

According to other characteristics of the invention:

the pressure measurement section comprises axial displacement guiding means for the transmission spacer;

the spacer has an axial rod provided, at least at one of its axial ends, with an axial support plate, the external face of which is adjacent and substantially parallel to the internal face of the associated closure element, when the spacer occupies its rest position;

the rod comprises a support plate at each one of its axial ends;

the area of the external face of each support plate is substantially equal to the area of the internal face of the associated closure element;

each of the closure elements and each of the support plates has substantially the shape of a disc;

the internal face of the main wall and the internal face of the secondary wall each comprise a rim, around the associated closure element, which extends axially towards the inside and which delimits a section of guide tube of a diameter substantially equal to the diameter of the associated support plate, for the purpose of axially guiding the transmission spacer;

the transmission spacer is attached to one of the closure elements;

at least one closure element is made in a single piece with the associated rigid wall, and the transmission spacer is made in a single piece with one closure element which is made in a single piece with the associated rigid wall;

the transmission spacer is made by moulding with a closure element which is itself made by moulding with the associated rigid wall;

the transmission spacer is secured in axial displacement to the secondary closure element;

the area of the secondary closure element is substantially twice the area of the main closure element;

the pressure measurement section comprises a sensor which identifies the direction of the axial displacement of the secondary closure element, so as to determine whether the axial force measured by the load sensor corresponds to a measurement of blood pressure which is above or below the pressure of the ambient air.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantages of the invention will appear on reading the following detailed description, for the understanding of which reference may be made to the appended drawings in which:

FIG. **1** is a cross-sectional schematic view showing a first type of pressure measurement system according to the prior art;

FIG. 2 is a view, similar to that of FIG. 1, which shows a second type of pressure measurement system according to the prior art;

FIG. 3 is a view, similar to that of FIG. 1, which shows an improvement to the pressure measurement system of FIG. 2 according to the prior art;

FIG. 4 is a perspective view which shows schematically an extracorporeal blood treatment device made according to the teachings of the invention;

FIG. 5 is a top view which shows schematically the cassette of the device of FIG. 4;

FIG. 6 is a view, similar to that of FIG. 1, which shows a pressure measurement section of the device of FIG. 4, according to the teachings of the invention;

FIG. 7 is a schematic perspective view which shows the transmission spacer of the pressure measurement section of FIG. 6;

FIG. 8 is a view, similar to that of FIG. 1, which shows a variant of the pressure measurement section of FIG. 6 comprising closure elements moulded in their associated rigid walls.

In the following description, identical or similar elements will be denoted by identical references.

FIG. 4 shows an extracorporeal blood treatment device 40 for the purpose of carrying out dialysis.

DETAILED DESCRIPTION OF THE INVENTION

This device 40 is designed to take blood from a patient, to treat it for the purpose of carrying out dialysis, then to reintroduce it into the body of the patient.

This device 40 comprises an extracorporeal blood circuit 42 (here shown only in part) having pipes 44 and comprising at least one section 46 for measuring the pressure of blood flowing in a pipe 44.

In this case, part of the extracorporeal blood circuit 42 is formed by a substantially parallelepipedal casing 48, also called cassette, which contains in its thickness pipes 44 for the blood flow, which are connected to other pipes 44 of the extracorporeal blood circuit 42.

In this case, the cassette 48 comprises two similar pressure measurement sections 46 which are contained therein.

The cassette 48 is designed to be mounted on a support plate 50 of a dialysis apparatus 52 which comprises, in particular, pumping means 54 to make the blood flow in the circuit 42 and means for controlling certain parameters of the circuit 42, in particular load sensors 56 which engage with the sections 46 in order to control the pressure in the pipes 44 of the circuit 42.

The cassette 48 is made, for example by moulding, of polycarbonate or polypropylene or of another suitable material.

In the rest of the description, only a single section 46 will be described.

The pressure measurement section 46, which is shown schematically in FIG. 6, in this case forms a substantially parallelepipedal compartment 58 which is inserted between two branches 60, 62 of a pipe 44, and which is for example moulded with the cassette 48.

According to an alternative embodiment (not shown) of the pressure measurement section 46, the latter may be a module attached to the cassette 48.

The compartment 58 is delimited especially by a main wall 64 and a secondary wall 65 which are substantially rigid and parallel.

The main wall 64 includes a hole 66 which is sealed by a main closure element 68, the internal face 70 of which is in contact with the blood and the external face 72 of which is in contact with the ambient air.

In the rest of the description, an axial orientation will be defined as following an axis A—A which is substantially orthogonal to the general plane of the main wall 64 and which passes through the centre of the hole 66.

When the cassette 48 is mounted on its support plate 50, the main wall 64 of the pressure measurement section 46 is designed to be placed facing the support plate 50, so that the main closure element 68 is facing a load sensor 56.

FIG. 5 shows the cassette 48 seen from the side of the main wall 64.

In this case, the main closure element 68 is a flexible membrane which is substantially disc-shaped.

In FIG. 6, the main membrane 68 has a peripheral torus-shaped beading 74 for its assembly in a complementary annular groove 76 which is made in the external face 78 of the main wall 64, in the vicinity of the hole 66.

A retaining ring 80 is fixed, for example by adhesive bonding, to the external face 78 of the main wall 64, over the torus-shaped beading 74, so as to axially retain the main membrane 68.

It is possible to deform the entire main membrane 68 along a deformation axis A—A which is substantially orthogonal to its general plane, under the effect of the blood pressure.

When the main membrane 68 is in its rest state, that is, when it is not deformed, since the blood pressure is substantially equal to the ambient air pressure, the central part of its external face 72 is in contact with a load transmitter 82, itself attached to a load sensor 56.

The load sensor 56 measures the force applied axially to the internal face 70 of the main membrane 68 by the blood pressure, in order to calculate therefrom the value of the said pressure.

Advantageously, the load sensor 56 is of the strain gauge type.

Note that when the system is in the rest state, the main membrane 68 is lightly tensioned, that is elastically deformed, by the force transmitter 82, by an initial axial pressing force F_0 , so as to guarantee contact between the main membrane 68 and the force transmitter 82.

In accordance with the teachings of the invention, the compartment 58 comprises, in its secondary wall 65, facing the hole 66 of the main wall 64, a secondary hole 84 which is sealed by a secondary closure element 86 similar to the main closure element 68, in this case by a secondary flexible membrane.

The secondary membrane 86 is attached to the external face 88 of the secondary wall 65 in a manner similar to the main membrane 68, by a secondary retaining ring 90.

Advantageously, the secondary ring 90 is almost closed, which makes it possible to protect the secondary membrane 86, and it therefore includes a central orifice 91 of small diameter.

The central orifice 91 makes it possible to put the external face 93 of the secondary membrane 86 in contact with the ambient air.

The deformation axis A—A of the secondary membrane 86 is substantially coincident with that of the main membrane 68.

The area of the internal face 92 of the secondary membrane 86 is greater than the area of the internal face 70 of the

main membrane **68** such that, when the blood pressure is less than the ambient air pressure, the axial deformation of the secondary membrane **86** in the direction of the main membrane **68** is greater than the axial deformation of the main membrane **68** in the direction of the secondary membrane **86**.

The compartment **58** also comprises a transmission spacer **94** which is inserted axially between the two membranes **68**, **86**.

When the blood pressure and the ambient air pressure are substantially equal, the spacer **94** occupies a rest position in which it is in contact, by a main axial end **96**, with the internal face **70** of the main membrane **68** and, by a secondary axial end **98**, with the internal face **92** of the secondary membrane **86**.

In this case, the spacer **94** has the overall shape of a “bobbin”, as shown in FIG. 7.

It comprises an axial rod **100** which is fitted, at each of its axial ends, with an axial support plate **96**, **98**, or end plate, the external face **102**, **104** of which is adjacent and substantially parallel to the internal face **70**, **92** of the associated membrane **68**, **86**, when the spacer **94** is in its rest position.

Each support plate **96**, **98** in this case has the overall shape of a disc, the diameter of which is substantially equal to the diameter of the internal face **70**, **92** of the associated membrane **68**, **86**.

Advantageously, the internal face **106** of the main wall **64** and the internal face **108** of the secondary wall **65** each have a rim **110**, **112**, around the associated hole **66**, **84**, which extends axially towards the inside and which delimits a guide tube section with a diameter substantially equal to the diameter of the associated support plate **96**, **98** of the spacer **94**, for the purpose of axially guiding the transmission spacer **94**.

The axial guiding of the spacer **94** makes it possible to prevent it being offset transversely, or about a rotation axis which is substantially transverse with respect to the deformation axis A—A of the membranes **68**, **86**.

Note that the spacer **94** is made, preferably by moulding of a light material, for example of polycarbonate or polypropylene.

When the blood pressure in the compartment **58** is greater than the ambient air pressure, that is when the pressure is called “positive”, the spacer **94** does not affect the operation of the membranes **68**, **86** since the two membranes **68**, **86** are deformed axially towards the outside, moving away from the spacer **94**, the main membrane **68** applying a main axial pressing force F_p against the force transmitter **82**.

The absolute value of the main force F_p can thus be expressed as follows:

$$F_p = F_0 + p \cdot S_p \quad (2)$$

In this equation (2), F_0 is the initial axial pressing force measured by the load sensor in the rest state of the pressure measurement system, p is the difference between the blood pressure and the ambient air pressure which are applied to the membranes **68**, **86**, and S_p is the area of the active surface of the main membrane **68**.

When the blood pressure in the compartment **58** is less than the ambient air pressure, that is when the pressure is called “negative”, the two membranes **68**, **86** tend to be deformed axially towards the inside of the compartment **58**.

The main membrane **68** then exerts a main axial pressing force F_p on the external face **102** of the main plate **96** directed towards the secondary membrane **86**, and the sec-

ondary membrane **86** then exerts a secondary axial pressing force F_s on the external face **104** of the secondary plate **98** directed towards the main membrane **68**.

The two forces F_p , F_s are therefore in opposite directions.

The absolute value of the main force F_p can be expressed as follows:

$$F_p = p \cdot S_p \quad (3)$$

In this equation (3), p is the difference between the blood pressure and the ambient air pressure which are applied to the membranes **68**, **86**, and S_p is the area of the active surface of the main membrane **68**.

The absolute value of the secondary force F_s can be expressed in a manner similar to equation (3), as follows:

$$F_s = p \cdot S_s \quad (4)$$

In this equation (4), S_s is the area of the active surface of the secondary membrane **86**.

By design, the area S_s of the active surface of the secondary membrane **86** is greater than the area S_p of the active surface of the main membrane **68**.

The secondary force F_s is therefore greater than the main force F_p .

Advantageously, a secondary active surface S_s is chosen, the area of which is equal to twice that of the main active surface S_p .

The absolute value of the secondary force F_s can then be expressed as follows:

$$F_s = 2p \cdot S_p \quad (5)$$

The absolute value of the resultant axial force F_r , which is applied to the load transmitter **82** and which is directed from the main membrane **68** to the load sensor **56**, is then expressed as follows:

$$F_r = F_0 + F_s - F_p = F_0 + p \cdot S_p \quad (6)$$

In this equation, F_0 is the initial axial pressing force, or pretensioning force, which is measured by the load sensor in the rest state of the pressure measurement system.

Consequently, for the same pressure difference p , the resultant force F_r of equation (6) and the main force F_p of equation (2) are equal.

For the same pressure difference p , whatever the direction of the pressure variation, the load sensor **56** will measure an identical value of force F_r and it will therefore calculate therefrom a same value of blood pressure.

Note that the spacer **94** makes it possible to transmit the resultant force F_r to the main membrane **68** and therefore to the load transmitter **82**.

Note also that the load sensor **56** is not capable of determining whether the axial pressing force that it measures corresponds to a positive or negative blood pressure.

According to an alternative embodiment (not shown) of the invention, an additional sensor is placed in the vicinity of the central part of the external wall **93** of the secondary membrane **86**, so as to detect, for example, a possible axial deformation of the secondary membrane **86** towards the outside.

If the additional sensor detects such an axial deformation, it can then be deduced that the force measured by the load sensor **56** corresponds to a positive pressure, otherwise it can be deduced that the force measured by the load sensor **56** corresponds to a negative pressure.

It is found that the greater the difference between the area of the internal face **70** of the main membrane **68** and the area

of the internal face 92 of the secondary membrane 86, the more the sensitivity and efficiency of the negative pressure measurement increases.

However, the area of the internal face 70 of the main membrane 68 should not be too small otherwise the mechanical ability for axial deformation of the main membrane 68 is decreased and the sensitivity of the main membrane 86 to the resultant force F_r , transmitted by the spacer 94, is decreased.

According to an alternative embodiment (not shown) of the invention, one of the support plates 96, 98 of the transmission spacer 94 is attached by known means to the associated membrane 68, 86, for example by adhesive bonding.

Note that the transmission spacer 94 should not be attached to the two membranes 68, 86, otherwise, in the case of positive pressure, the secondary membrane 86 would cause the main membrane 68 to be axially displaced towards the outside, on the side opposite the load transmitter 82, which would distort the measurements carried out by the load sensor 56.

FIG. 8 shows an alternative embodiment of the invention in which the closure elements 68, 86 of the holes 66, 84 of the main wall 64 and the secondary wall 65, respectively, are each made in a single piece with the associated wall 64, 65.

In this case, each closure element 68, 86 comprises a disc-shaped substantially rigid central pellet 114, 116, which is delimited by a thinned peripheral annular region 118, 120 with an axial thickness less than the axial thickness of the associated rigid wall 64, 65, so as to form an elastically deformable region.

Thus, under the effect of the blood pressure in the compartment 58, and by virtue of the elastic deformation of its thinned region 118, 120, it is possible for each central pellet 114, 116 to be displaced overall along a displacement axis which is substantially orthogonal to the general plane of the pellet 114, 116 and which corresponds to the deformation axis A—A of the membranes 68, 86 of the embodiment shown in FIG. 6.

In its rest state, the external face 72 of the central pellet 114 of the main closure element 68, or main pellet 114, is in contact with the load transmitter 82.

Advantageously, the transmission spacer 94 is made in a single piece, in this case by moulding, with the central pellet 116 of the secondary closure element 86, or secondary pellet 116.

In the embodiment which is shown here, the transmission spacer 94 has the shape of a frustoconical finger, the base 98 of which is moulded on the internal face 92 of the secondary pellet 116 and the free axial end 96 of which bears axially against the internal face 70 of the main pellet 114, when the system is in its rest state.

Of course, it is possible to combine the different characteristics which have been described above, without departing from the field of the present invention.

What is claimed is:

1. Device for measuring the pressure of blood in a pipe (44) of an extracorporeal blood circuit (42), comprising a pressure measurement section (46) having a compartment (58) which is delimited especially by a main wall (64) and by a secondary wall (65) facing the main wall (64), the two walls (64, 65) being substantially rigid and parallel, the main wall (64) having a hole (66) which is sealed by a main closure element (68) having an internal face (70) which is in contact with the blood and an external face (72) which is in contact with the ambient air, the entire main closure element (68) being elastically deformable or displaceable along a

deformation or displacement axis (A—A), which is substantially orthogonal to its general plane, under the effect of the blood pressure, the main closure element (68) being designed to engage with a load sensor (56) so that a portion of the external face (72) of the main closure element (68), in its rest state, is in direct or indirect contact with the load sensor (56) which can measure the force applied axially to the internal face (70) of the main closure element (68) by the blood pressure, in order to calculate therefrom the value of this pressure, characterized in that the pressure measurement section (46) comprises:

in its secondary wall (65), facing the hole (66) of the main wall (64), a secondary hole (84) which is sealed by a secondary closure element (86) having a deformation or displacement axis (A—A) which is substantially coincident with that of the main closure element (68), the area of the internal face (92) of the secondary closure element (86) being greater than the area of the internal face (70) of the main closure element (68), such that when the pressure of the blood is less than the pressure of the ambient air, the axial displacement of the secondary closure element (86) towards the main closure element (68) is greater than the axial displacement of the main closure element (68) towards the secondary closure element (86);

and comprising, in the compartment (58), a transmission spacer (94) which, when the pressure of the blood and the pressure of the ambient air are substantially equal, occupies a rest position in which the transmission spacer (94) is in contact by a first axial end (96) with the internal face (70) of the main closure element (68) and, by a second axial end (98), with the internal face (92) of the secondary closure element (86);

such that when the blood pressure is less than the ambient air pressure, the spacer (94) transmits the axial displacement, in the direction of the load sensor (56), from the secondary closure element (86) to the main closure element (68), so that the load sensor (56) can measure the resultant axial force in order to calculate therefrom the value of the blood pressure.

2. Device according to claim 1, characterized in that the pressure measurement section (46) comprises axial displacement guiding means (110, 112) for the transmission spacer (94).

3. Device according to claim 1, characterized in that the spacer (94) has an axial rod (100) provided, at least at one of its axial ends, with an axial support plate (96, 98), the external face (102, 104) of which is adjacent and substantially parallel to the internal face (70, 92) of the associated closure element (68, 86), when the spacer (94) occupies its rest position.

4. Device according to claim 3, characterized in that the rod (100) comprises a support plate (96, 98) at each one of its axial ends.

5. Device according to claim 3, characterized in that the area of the external face (102, 104) of each support plate (96, 98) is substantially equal to the area of the internal face (70, 92) of the associated closure element (68, 86).

6. Device according to claim 3, characterized in that each of the closure elements (68, 86) and each of the support plates (96, 98) has substantially the shape of a disc.

7. Device according to claim 3, characterized in that the internal face (106) of the main wall (64) and the internal face (108) of the secondary wall (65) each comprise a rim (110, 112), around the associated closure element (68, 86), which extends axially towards the inside and which delimits a section of guide tube of a diameter substantially equal to the

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diameter of the associated support plate (96, 98), for the purpose of axially guiding the transmission spacer (94).

8. Device according to claim 1, characterized in that the transmission spacer (94) is attached to one of the closure elements (68, 86).

9. Device according to claim 1, characterized in that at least one closure element (68, 86) is made in a single piece with the associated rigid wall (64, 65), and in that the transmission spacer (94) is made in a single piece with one of the closure elements (68, 86) which is made in a single piece with the associated rigid wall (64, 65).

10. Device according to claim 9, characterized in that the transmission spacer (94) is made by moulding with a closure element (86) which is itself made by moulding with the associated rigid wall (65).

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11. Device according to claim 8, characterized in that the transmission spacer (94) is secured in axial displacement to the secondary closure element (86).

12. Device according to claim 1, characterized in that the area of the secondary closure element (86) is substantially twice the area of the main closure element (68).

13. Device according to claim 1, characterized in that the pressure measurement section (46) comprises a sensor which identifies the direction of the axial displacement of the secondary closure element (86), so as to determine whether the axial force measured by the load sensor (56) corresponds to a measurement of blood pressure which is above or below the pressure of the ambient air.

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